1.0 RESEARCH GOALS

1.1 Introduction to the Research Plan

In 1997, the South Florida Water Management District undertook an Estero Bay and Watershed Management and Improvement Plan, a multi-year project. The District's prime consultant, PBS&J, is charged with conducting an Estero Bay Assessment and an Estero Watershed Assessment. The watershed assessment will develop land and water management strategies to achieve water quality and quantity objectives for the Bay. Major assessment activities include physical descriptions of major features and current management practices, identification of water quality trends, ranking of potential pollution problem areas, and compilation of input data for a watershed model to evaluate management scenarios. A subsequent assessment phase utilizes modeling for scenario evaluation.

The Estero Bay Assessment will define water quality and water quantity objectives or pollution load reduction goals for the Bay and develop tools to evaluate the effects of watershed management techniques on the Bay. The Estero Bay Assessment involves the application of a logical protocol for designing study and management plans, to identify the types of pollutants and their impacts on estuarine environments. The first and present phase of the assessment will result in an Estero Bay Research Plan, based on management goals for the estuary. A subsequent assessment phase implements the research plan.

The Estero Bay Research Plan follows a method developed by Mote Marine Laboratory for the South Florida Water Management District's study of south Florida estuaries, applied first to the St. Lucie River and estuary. First, goals are established for the Bay. Next, research questions appropriate to each goal are identified. Finally, specific analytical methodologies are defined to answer each research question. Taken as a whole, these tasks will comprise the Estero Bay Research Plan.

Goals are identified through an analysis of existing laws, rules, policies, and other statements of social expectations for the Bay ("authorities"). These same sources provide insight to the valued ecosystem components of the Bay. Primary goals are developed around each major ecosystem component, and are written to meet criteria of meaningfulness, verifiability, and practicality. Secondary goals are identified around stressors known or suspected to play a significant role in regulating the condition of valued ecosystem components. Where needed, tertiary goals may be identified in order to complete a causal link between valued ecosystem components, and management actions.

This report summarizes a review of authorities made for the purpose of identifying ambitions for, and valued ecosystem components of, Estero Bay. Goals are recommended. These goals will be used in the next project task to develop empirical questions of two forms: one form seeks to establish status and trends of the estuary, and the other form asks questions regarding controlling processes. Such questions will guide the definition of analytical methods which, if implemented in the second

phase of the Estero Bay Assessment, are expected to generate information useful in the definition of water quality and water quantity objectives or pollution load reduction goals for the Bay.

1.2 Estero Bay and Bay Science

Estero Bay is a small estuary on the southwest coast of Florida. Long known to fishermen and nature enthusiasts as a productive and beautiful environment, it otherwise was relatively un-noticed by the general public or state resource managers until after World War II. As the population of Lee County grew, so also did pressures to develop in and near the Bay. Efforts to protect the Bay grew as well, and most of what is known about the Bay is the result of the tension between growth and preservation.

Two periods may be noted as high-water marks for the generation of scientific information on Estero Bay. The first accompanied unsuccessful plans in the early 1970s to develop a large tract of lands fringing the Bay (Estuaries Properties, 1975). The "Estuaries" proposal generated considerable public support for Bay protection. Legal arguments surrounding the proposal eventually led to landmark decisions favoring the State of Florida's authority to regulate development in and near sovereignty lands. Studies of the Bay made by the developers and state added much to our present knowledge of the Bay, and in many respects form the earliest or baseline information available on bay ecology.

The second significant period for science in Estero Bay began in the 1990s and has continued through the present. It too has been propelled in large measure by the tension between intense development, and growing public stewardship campaigns. Two features distinguish the present phase. First, more individual studies have been made, or are underway, than in any comparable period of time. Second, investigators are seeking to paint synthetic, comprehensive pictures of the Bay, rather than representing the Bay as a collection of separate, independent facts.

In just the past few years, information on hydrology, water quality, and biology has been collected in common essays about the Bay. These often include information on the Bay's prehistory and history, recreational uses, or future security. The best examples of such syntheses may be found in the "Strategic Plan for Southwest Florida" by the Southwest Florida Regional Planning Council; the "Lee County Comprehensive Plan" and its exhibits and appendices; the "State of the Bay Report" in production by a committee of the Estero Bay Agency on Bay Management, and the annual "Research Studies in Estero Bay Aquatic Preserve," by the Estero Bay Marine Laboratory. A report by W. Dexter Bender and Associates entitled, "Managing the Quality, Quantity, and Timing of Surface Water Discharge into the Estero Bay State Aquatic Preserve" is a succinct synthesis of Bay ecology derived from principles of estuarine science. The "Estero Bay Aquatic Preserve Management Plan" also deserves notice as a 1980s era effort in the same vein.

The present effort, design of an Estero Bay Research Plan, will in subsequent project phases examine what is known of the Bay is considerable detail. In addition to the reports cited above, reports by state and county agencies, unpublished raw data, and other sources of information will be assimilated. A preliminary review of this information has been made for the purposes of A) characterizing dominant features of the Bay, and B) assessing the types and amounts of data generally available to the undertaking. Results are summarized below, for major study subjects.

1.2.1 Geography

Watershed boundaries are better defined than in the past (but see below). The bathymetry of the Bay itself may be out of date, especially near inlets and river mouths. A shoreline survey of the Bay is needed to characterize types and conditions of shorelines, changes through time, and potential future conflicts.

1.2.2 Geology

The geology of Estero Bay has never been studied, except for very recent work by the Estero Bay Marine Laboratory (1996) on sediment and core analyses. Possible reasons include the Bay's relative isolation from Charlotte Harbor, comparatively shallow nature, or absence of the federally authorized Intra-Coastal Waterway. In any event, information is lacking on structural geology, sediment dynamics, and other basic aspects. Beach and inlet dynamics have been studied more than Bay geology. The Bay is exceptionally shallow, raising a number of interesting questions. How the bay maintains such shallow depth during the past few centuries of [relatively slow] sea level rise exemplifies such questions. The role of mollusks (oysters and clams) in supplying sediment to the Bay also deserves investigation.

1.2.3 Hydrology

Compared to other Florida estuaries, the watershed is considerably larger than Estero Bay. The Bay may be expected, therefore, to be affected significantly by hydrological changes in the watershed. Subbasin boundaries are better known than previously, but in many places the boundaries are ambiguous, and vary according to water levels. Either because of its natural topography, or because of human-caused changes to drainage, the watershed is susceptible to flooding. Flood studies are numerous, and represent the single most-studied aspect of the Bay and its environs. Oddly, therefore, discharge measurements are uneven and records are incomplete. Historic emphasis was placed on stage rather than flow, seriously affecting estimations of nutrient or contaminant loads to the Bay in past years. Flooding in 1995 has kindled new interest in providing flood relief. The District and County are evaluating the feasibility of increasing Estero River discharges, in the context of flow restoration. Several studies are underway as a result.

1.2.4 Hydrography

As mentioned, the Bay is exceptionally shallow. Average tide range exceeds mean bay depth, meaning there is a large potential for tidal action to affect Bay circulation and flushing. Natural tributaries to Estero Bay are short, and small. Their historic flows are largely unknown, but probably were low, and changed gradually in all but the largest storm events, meaning that the eastern side of the Bay was most affected by river discharges. The Rivers have no outlet channels-- the channels end abruptly upon entering Estero Bay, further signifying relatively low discharges. Inlets from the Gulf of Mexico also are small, and dynamic. Inlets have minor channel systems penetrating into the Bay. These circumstances suggest that circulation is different during high tides than low. Circulation characteristics are largely unknown, but under study. The Bay's zones of minimal tidal exchange, or "null zones" are known. Their location, size, and chemistry will be important variables to consider in bay science and management. Finally, given the Bay's shallow nature, wind is probably a dominant controlling factor over circulation.

1.2.5 Sediments

Bay sediments have been studied, and are being studied, but there is no map of bay sediments as of yet. Most sediment studies have been made in the central and northern reaches of the Bay. Granulometry is known for many stations, although data on the mineralogy of sediments are needed. As mentioned previously, mollusks may play a significant role in the Bay's sediment budget. But we also need to know the extent to which land-based sediments are involved in the bay bottom. There is a strong possibility that Gulf sediments are also a major factor in the Bay's sediment budget. The thickness of sediments must also be learned. Metals have been studied more than once. Metals originate from uplands and tend to associate with fine particulate matter in the Bay. Metals sometime exceed concentrations normalized to Aluminum, signifying enrichment. Metal "hot-spots" are known in the Bay, and also are thought to disappear after floods.

1.2.6 Fresh Water and Salinity

The Bay is tidally dominated in dry seasons, and salinity is highest. Historic salinity data are available to compare with modern salinity data, at least for central and northern Estero Bay. Salinities tend to be uniform and high throughout the long axis of the Bay. Rivers and major creeks are outlets of fresh water, but their beds are below sea level to US 41 and, in some cases, almost to Interstate 75. This implies that streams are filled with tide water during dry seasons and droughts. Low salinity reaches are compressed into streams. Strong salinity gradients occur along the eastern side of the bay during times of non-zero river flow, but attenuate rapidly. Floods like that of 1995 completely freshen the bay, but not inlets. Hell Peckish Bay is thought to be fresher than expected given its position in the Bay. The bay may be receiving a significant amount of groundwater. Rates of groundwater efflux and its effect on bay salinity are unknown but deserve study.

1.2.7 Water Quality

Estero Bay is designated an Outstanding Florida Water, and classified as Class II and Class III waters of the state. Studies have been spotty but are improving, especially in streams. Water quality baselines exist for Ten Mile Canal, Six Mile Cypress, and the Estero and Imperial Rivers. Some modeling is available to forecast future water quality. Loads of nutrients and contaminants are expected to increase most in the basins yet to be developed fully. Historical bay water quality data are more limited. The middle Bay has been studied the most and the southern Bay, the least. Lee County data indicate that overall water quality in the Bay, since 1991, has been exceptionally high. The bay is closed to shell fishing, by default for being unclassified. Water quality indices range from fair to good. Hypoxic and anoxic conditions are being reported in shallow water. If supported by additional monitoring, processes responsible for this unusual finding deserve detailed study because low oxygen is unexpected in such a shallow Bay, especially one lacking extensive submerged vegetation.

1.2.8 Ecology

There is considerable disagreement over historic versus modern area of the Bay supporting submerged aquatic vegetation. An early map and the reports of a developer's consultant indicate more SAT than presently occurs. A similar trend is suggested from 2 eras of state SAT mapping in the Bay, and recent work by Lee County, and the Estero Bay Marine Laboratory. On balance, historic agency maps were based on photo-interpretation without ground-truthing, and examination of historic aerial photographs suggests that seagrasses per se may not have been extensive. This is an unsettled issue with significant implications for Bay science and management. Drift macroalgae has recently been cited as a problem. Most non-SAT habitat loss has been via shoreline alteration. On balance, large expanses of native wetlands still fringe the Bay and grow as islands. Bivalves are abundant, but under-studied. Historic data on specific oyster reefs are available. Bivalves may play an important role in regulating water quality and biological processes in so shallow a Bay. The bay harbors manatees and crocodiles (endangered species). Avifauna diversity is particularly high, and CREW (Corkscrew Regional Ecosystem Watershed) contains a number of listed species exceeded by only a few sites in Florida.

1.2.9 Management

Management programs have intimate links to research, for research describes the status and trends of valued resources. Research also gives insight to basic processes affecting resources, and explains how specific stressors exert their [usually undesirable] effects. Actual resource problems facing Estero Bay are poorly documented. Closure of shellfish beds is a definite indicator, as are areas and times when water quality indices are less than good. As documented in the next section, calls for preservation, non-degradation, and restoration are numerous. Laws and policy documents recognize freshwater inflow as a priority item. The bay and tributaries are Outstanding Florida Waters, signifying an intent that no degradation of water quality shall occur. Given that flood control is the

biggest land-side issue facing the bay, followed by eutrophication as the biggest water-side issue, maintaining a no-degradation standard will require much new, targeted research. Navigational channels are another emerging water-side issue.

1.2.10 Inferences and Conclusions

Estero Bay is not a data-deficient system, but there exist a number of subjects for which data are insufficient to support analytical assessments of cause and effect, or to support predictions of Bay response to proposed changes, including restoration or mitigation. Likewise, much less seems known of the southern Bay than other reaches. Except for the SAT issue, most sources feel the bay is in good shape, or just beginning to manifest symptoms of decline. In other words, compared to many other bays with active management programs, there are few well-documented problems to fix. Science in Estero Bay will not be driven so much by problem resolution, as by the need to understand basic processes affecting resources of value, which resources are meant to be preserved or enhanced. Research plans recommended for the Bay must therefore seek to meet three objectives-- discover as much as possible of basic processes; be applicable to the management of valued resources, and advance social expectations for the Bay. The following section reviews laws, policies, and programs to identify valued resources and goals for Bay management.

1.3 Research Goals

1.3.1 On the Nature of Goals in Research

The Research Plan for Estero Bay seeks to be goal-driven, which is to say that recommended research will be referable to explicit end-points. Such goals or end-points could be purely scientific, usually meaning that the absence of particular kinds of knowledge is sufficient to justify recommended research. A research plan developed against such standards risks being so broad in scope that it could never be conducted except as a philanthropic or volunteer effort.

The Estero Bay plan intends that recommended research be basic in nature, i.e., result in new discoveries about the structure and function of the Bay, but that such discoveries also be applicable to contemporary issues of Bay management. Properly crafted, the research plan will identify those particular investigations having, as a whole, a high probability of being useful to resource managers. In order to recommend investigations it is therefore useful to a) understand existing expectations of society relative to Estero Bay, b) identify valued ecosystem components recognized by laws and policies, and c) define research goals that track such resources and expectations as closely as possible, while recognizing the underlying need for basic research.

Good goal statements have three qualities-- they are meaningful, verifiable, and practical. As used here, "meaningful" means that a material improvement to the estuary would follow if the goal was accomplished. "Verifiable" means that an independent observer can determine whether the goal has

been met through the use of accepted methods. "Practical" means that the goal does not depend on technology that does not yet exist. A goal does not necessarily have to be legal or affordable to be practical, because legality and economy are changeable social values.

Management goals for estuaries are usually not specific enough to be useful in the design of scientific studies (Estevez, 1991), although this problem has been recognized and efforts have been made to generate better goal statements in other estuaries (Agency on Bay Management, 1990; Kenworthy and Haunert, 1991).

In south Florida, Estevez and Hayward (1992) identified methods by which management goals may be crafted, beginning with a review of:

- General federal and state laws and water quality programs such as the national Clean Water Act and the Florida Water Resources Act;
- Specific management programs at the federal level, such as estuarine and marine sanctuaries, research reserves, wild and scenic river plans, national park management plans, national estuary program plans, et cetera;
- Specific management programs at the state level, such as aquatic preserve plans, outstanding Florida water designations, state park and recreation area management plans, state wild and scenic river plans, et cetera;
- Specific management programs at the regional and local (and private, if appropriate) levels, such as SWIM plans, District surface water programs, local government comprehensive plans, and single mission plans for flood control, mosquito control, soil conservation, et cetera.

Collectively, these "authorities" establish a legal and policy landscape within which existing or prospective information about Estero Bay can be evaluated, for the purpose of establishing research goals. This process anchors the recommended research in the most favorable context for resource management.

1.3.2 Existing Authorities

The following section provides brief descriptions, and assessments for Estero Bay research, of numerous authorities (**Table 1**). Parts of federal/state summaries were adapted from Estevez (1992). A few authorities involve committees comprised of

federal, state, and local governments, plus other interested parties or stakeholders. These are listed at the government level of the lead agency, or reporting agency.

I. Federal Guidance

A number of federal laws directly or indirectly affect science and management of Estero Bay. Some, such as the Endangered Species Act and Marine Mammal Protection Act, protect species of special concern by conserving the ecosystems upon which endangered species and seeking an optimum sustainable population keeping in mind the carrying capacity of the habitat.

Such acts call for the development of recovery or management plans, for which none exist for Estero Bay. The laws do reserve rights for the federal government to intervene as needed.

Other federal laws have a more direct bearing on science and management of Estero Bay. The Clean Water Act provides for research and training; grants for construction of treatment works; standards and enforcement; water quality inventories; permits and licenses; and a state water pollution control revolving fund. In addition, Section 320 establishes the National Estuary Program, of which more information is given below.

The objective of the Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Goals of the Act include:

1. To eliminate the discharge of pollutants into navigable waters;
2. Until discharges are eliminated, to achieve an interim goal of water quality which provides for the protection and propagation of fish, shellfish and wildlife;
3. To prohibit the discharge of toxic pollutants in toxic amounts;
4. To provide federal financial assistance to construct publicly owned waste treatment works;
5. To develop and implement area-wide waste treatment management plans and technology;
6. To develop and implement controls of nonpoint sources of pollution.

The main aim of the Clean Water Act is to curtail the discharge from point and nonpoint sources of pollutants such as domestic waste waters, sewage sludge, thermal pollution, oil at sea, and similar constituents. The Act intends that discharges of pollutants into Estero Bay be eliminated. As part of U.S. Environmental Protection Agency (EPA) requirements of states, Florida makes biennial reports on the water quality status of state waters, including Estero Bay.

Another important federal program bearing on Estero Bay is the Central and Southern Florida Project for Flood Control, prepared by the U.S. Army Corps of Engineers. This program, precursor to the establishment of the South Florida Water Management District, provided for studies and capital investments intended to protect human life and property from floods; manage water for agriculture and public supply, and provide water needed for the maintenance of natural systems. Changes to the Project affecting flood control and freshwater supplied south Florida, including Estero Bay, are being studied, and an environmental impact assessment must be developed. Terms and conditions of the

environmental impact statement presently are being negotiated with state and local governments, and it is too early to foresee implications for Estero Bay research or management. However, some objectives of the C&SF Restudy are pertinent to Estero Bay:

1. Increase the total spatial extent of natural areas.
2. Improve habitat and functional quality.
3. Improve native plant and animal species abundance and diversity.
4. Improve availability of fresh water (for human uses).
5. Reduce flood damages in agricultural and urban areas.

As part of work by the South Florida Ecosystem Restoration Working Group's Science Subgroup, a Big Cypress Basin Issues Characterization Workshop Report was issued in 1997. As used by this group, the Big Cypress Basin was meant to include Estero Bay. The workshop compiled concerns regarding hydrology, water quality, and biota, and also information needed to address the concerns. Estero Bay was mentioned infrequently although many general statements were made with the intent that Estero Bay be included. Issues most supported by the group were lack of data on hydrologic budgets, and long-term vs. short-term hydrologic variation; impacts of land use on water quality; and the need for biological indicators of environmental quality, especially at regional scales. Numerous other issues were identified.

In terms of needed information, first level priority was given to hydrologic regimes and patterns, water budgets, and ecological inventories. Second level priority was given to new information on habitat conversion, impacts from built structures, restoration of natural cycles, and regional biotic linkages. Third to fifth level information priorities also were listed.

No issues specific to Estero Bay were listed for hydrology, water quality, or biology. On balance, Estero Bay was named when the workshop was asked what must be learned in order to improve the Bay's management, to wit, the effect of canals, septic tanks, commercial and industrial polluters on water quality. The report is a useful summary of issues and data needs for the entire Big Cypress area, but is to general to guide priorities for a research plan specific to Estero Bay. At the same time, it is unlikely that a list of issues and data needs for Estero Bay would turn up items not already found on the Big Cypress list. Therefore, this work should be kept at hand as Estero Bay plans develop.

II. Federal - State Guidance

The State of Florida and EPA have entered a Charlotte Harbor National Estuary Program Management Conference Agreement, to begin a management conference as provided by Section 320 of the Clean Water Act. The Agreement provides for an assessment of trends in water quality, natural resources, and uses; determination of the causes of changes through data collection, characterization and analysis; evaluation of point and non-point loadings; a comprehensive conservation and management plan that indicates priority actions; implementation of the plan;

monitoring to assess the effectiveness of implementation; and review of federal programs for consistency. The Agreement lays forth a plan to identify and rank priority problems; develop a data and information management system; inventory relevant agency programs; produce a characterization report for the study area; prepare a financing plan for the final recommendations; and adopt a comprehensive conservation and management plan. The general thrust of the conference agreement is one of preservation of existing resource values and benefits, and restoration of these qualities where they have declined. Goals developed by the management conference are:

1. Improve the environmental integrity of the Charlotte Harbor study area.
2. Preserve, restore and enhance seagrass beds, coastal wetlands, barrier beaches, and functionally related wetlands.
3. Reduce point and non-point sources of pollution to attain desired uses of the estuary.
4. Provide the proper freshwater inflow to the estuary to ensure a balanced and productive ecosystem.
5. Develop and implement a strategy for public participation and education.
6. Develop and implement a formal Charlotte Harbor management plan with a specified structure and process for achieving goals for the estuary.
7. Develop an accessible information system that integrates data on the Charlotte Harbor study area pertinent to Harbor and watershed management.

III. State Guidance

In response to concerns over siting of Florida Gulf Coast University, including direct and secondary impacts on-site and off-site natural resources, the Arnold Committee Report and Recommendations set into motion a coordinated program of sustained resource management for southeast Lee County and Estero Bay. The report considered a number of land use issues (agriculture, natural preserves, mining, water supply, and institutional/urban uses). Regional transportation and flood control efforts also were reviewed. A high level of natural resource values were recognized. Threats to wildlife were identified and concern was stated for exotic species, ranching and farming, mining, and imperfect habitat mitigation. Considerable attention was given to surface water resources, flooding, and water supply.

The Arnold Report, on page 26, states that an Agency on Bay Management (ABM) will be created for Estero Bay, within the Southwest Florida Regional Planning Council. The ABM "will support the District in four areas; policy, technical advice, citizen support, and ...implementation" of EBMIP,

the Estero Bay Management and Implementation Plan of which this research plan is an element. The EBMIP is to be developed over a three-year period. The report notes,

> *"An Estero Bay Assessment will generate a research plan. The research plan will establish goals which, when met, will improve and maintain the health of the bay's ecosystem. Because the ecology of the bay is only partially understood, much of this phase of the project will involve literature review, identifying data needs, selecting analytical methods, and prioritizing research."*

The report also notes that water quality in the bay is now considered fair-to-good but that some degradation is suspected to have occurred in recent years. The report states, "urban development has altered stormwater runoff **and perhaps salinity patterns** (emphasis added).

The Florida Water Resources Act (Ch. 373 FS) was based to a large extent on A Model Water Code developed by the University of Florida College of Law. The Act gives general supervisory authority over water management districts to the Florida Department of Environmental Regulation, which was directed to produce an "integrated, coordinated plan for the use and development of the waters of the state." The plan is to be part of the state comprehensive plan which, together with water quality standards and classifications, represent the Florida Water Plan.

The Act directs water management districts to set minimum flows and levels for surface waters, among other actions, using the criteria of reasonable and beneficial uses. The Act defines minimum flow as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." A policy of the Act is "to preserve natural resources, fish and wildlife." The Act directs the Florida Department of Environmental Protection (DEP) to consider "existing and contemplated needs and uses of water for protection and procreation of fish and wildlife" in preparing the state water use plan. In the administrative rule accompanying the Act[1] a general state water policy is to establish "minimum flows and levels to protect water resources and the environmental values associated with marine, estuarine, freshwater, and wetlands ecology." Minimum flows are to provide for recreation, fish and wildlife habitats and the passage of fish, estuarine resources, transfer of detrital material, and water quality, as well as other reasonable/beneficial uses.

The Act authorizes DEP and water management districts to reserve from permitted uses "water in such locations and quantities, and for such seasons of the year, as in its judgement may be required for the protection of fish and wildlife or the public health and safety." The Act addresses the problem of water use, consumption, or diversion. It focuses on management of the impacts of water extraction and does not explicitly refer to the impacts of excess water. However, recognition of

[1] Florida Administrative Code Rule 17-40.310 (11) (1990).

timing, amount and location as critical flow parameters clearly leaves open such considerations where Estero Bay is concerned.

Chapter 17-40 Florida Administrative Code -- Water Policy implements provision of the state water policy. It states that waters of the State should be managed to conserve and protect natural resources and scenic beauty and to realize full beneficial use of the resource. The rule provides that water management programs, rules, and plans shall seek to:

1. Reserve from use that water necessary to support essential non-withdrawal demands, including navigation, recreation, and the protection of fish and wildlife.
2. Utilize, preserve, restore and enhance natural water management systems and discourage the channelization or other alteration of natural rivers, streams, and lakes;
3. Mitigate adverse impacts resulting from prior alteration of natural hydrologic patterns and fluctuations in surface and ground water levels;
4. Establish minimum flows and levels to protect water resources and the environmental values associated with marine, estuarine, freshwater and wetlands ecology.

The rule specifies conditions to be considered in the establishment of minimum flows and levels. The rule states that a primary goal of the State's stormwater management program is "...to maintain the appropriate salinity regimes in estuaries needed to support the natural flora and fauna..." "Stormwater" is defined by the rule as the water which results from a rainfall event. The rule sets forth a number of policies and criteria pertinent to Estero Bay.

Chapter 17-43 Florida Administrative Code enacts the Surface Water Improvement and Management Act (Chapter 373.451 Florida Statutes). General goals of the Act are to manage waters so as to provide aesthetic and recreational pleasure; provide habitat for native plants, fish and wildlife, including endangered and threatened species; providing safe drinking water; and attracting visitors and accruing other economic benefits. The rule authorizes water management districts to prioritize waters in each district with respect to preservation and restoration. Districts are to prepare and triennially revise surface water plans for priority water bodies. Criteria for ranking and elements of the surface water plans are given. Arrangements for funding and DEP review are provided. It implies that some priority waters are to be preserved and others restored, "to meet Class III standards or better." The rule's intent states that it is the duty of the State...to enhance the environmental and scenic value of surface waters, but no other goals or policies are given other than administrative ones.

Chapter 403 Florida Statutes -- Environmental Control addresses pollution control, electrical power plant siting, resource recovery and management, drinking water, and other environmental issues. The Legislature declared as public policy to conserve the waters of the state and to protect, maintain, and improve the quality thereof for public water supplies, the propagation of wildlife and fish and

other aquatic life, and for domestic, agricultural, industrial recreational and other beneficial uses and to provide that no wastes be discharged into any waters of the state without being given the degree of treatment necessary to protect beneficial uses.

The Act defines contaminant as any substance which is harmful to plant, animal, or human life. Waste is defined as sewage, industrial waste, and all other liquid, gaseous, solid, radioactive or other substances which may pollute waters of the State. Pollution is defined as the presence of any substances, contaminants, noise, or man-made or man-induced impairment of air or waters or alteration of the chemical, physical, biological or radiological integrity of air or waters in quantities or levels which are or may be potentially harmful or injurious to human health or welfare, animal or plant life, or property.

The Act prohibits mixing zones for point source discharges in Outstanding Florida Waters, but states "Discharges of water necessary for water management purposes which have been approved by the governing board of a water management district and, if required by law, by the [DEP] secretary" are exempt from OFW standards. Definitions in the Act make it possible to interpret fresh water as a contaminant or waste subject to the Act. The Act exempts board-approved discharges of fresh water from OFW standards. This exemption implies a recognition that non-degradation standards of OFW are or may be violated by fresh water discharges. Because Estero Bay and its tributaries have been designated Outstanding Florida Waters, this Act's provisions have direct bearing on Bay science and management.

Chapter 17-302 Florida Administrative Code -- Surface Water Quality provides anti-degradation standards for surface water quality; a classification system for surface waters; minimum and general criteria; specific criteria; and protection for special areas. Definitions of interest include "exceptional ecological significance," meaning that a water body is part of an ecosystem of unusual value; "natural background" means the condition of waters in the absence of man-induced alterations; and "nursery area of indigenous aquatic life" means beds of submerged aquatic vegetation or other areas used in early development or growth.

A chloride concentration in surface waters of 1,500 milligrams per liter is used to distinguish "predominantly fresh water" from "predominantly marine water." The rule categorizes all waters of the State into one of 5 classes. Class II is for shellfish propagation and harvesting. Class III is for propagation and maintenance of a well-balanced population of fish and wildlife.

The rule provides general criteria which apply to all surface waters except in mixing zones. For Classes I, II and III waters, biological integrity cannot be reduced to less than 75% of background. (Biological integrity is defined in the rule as the Shannon-Weaver diversity index and Background is defined as condition of a water body in the absence of an activity or pollutant.) The rule designates all waters of the State as Class III except as specified. The Estero Bay Aquatic Preserve is designated as Class III waters, with Hurricane and Hell Peckish Bays designated as Class II waters.

The rule also designates aquatic preserves as Outstanding Florida Waters, for which it is Department policy to afford the highest protection. The Bay and its tributaries are OFW, as previously noted. State water quality standards for each class of waters therefore have considerable bearing on science and management of Estero Bay.

Chapter 16-20 Florida Administrative Code -- Aquatic Preserves. Florida law (73-534, Sections 258.39 -258.393) creates a system of aquatic preserves implemented and administered by this rule. Goals of the rule are to:

1. Maintain essentially natural conditions, propagation of fish and wildlife, and public recreation including hunting and fishing;
2. Continue the preserves' essentially natural or existing condition so that their aesthetic, biological, and scientific values may endure for the enjoyment of future generations;
3. Preserve, protect, and enhance these exceptional areas of sovereignty submerged lands by reasonable regulation and a comprehensive management program;
4. Protect and enhance the waters of preserves so that the public may continue to enjoy traditional recreational uses;
5. To coordinate with other agencies of government and to use their programs to assist in managing preserves;
6. To encourage the protection, enhancement or restoration of [preserve values] when reviewing applications and implementing management plans;
7. To preserve, promote, and utilize indigenous life forms and habitats, including but not limited to sponges, soft coral, hard coral, submerged grasses, mangroves, salt water marshes, fresh water marshes, mudflats, estuarine, aquatic and marine reptiles, game and non-game fish species, estuarine, aquatic and marine invertebrates, estuarine, aquatic and marine mammals, birds, shellfish, and mollusks;
8. To acquire additional title interests in lands to promote preserve values;
9. To maintain those beneficial hydrologic and biologic functions, the benefits of which accrue to the public at large.

The rule applies to all preserves except Boca Ciega Bay, Pinellas County and Biscayne Bay Aquatic Preserves. The rule includes the Estero Bay preserve. The rule establishes a zoning system for preserve management in the form of three Resource Protection Areas. The protection areas are to be used in decisions affecting docking facilities in aquatic preserves.

The rule defines "essentially natural condition" as "those functions which support the continued existence or encourage the restoration of the diverse population of indigenous life forms and habitats to the extent they existed prior to the significant development adjacent to and within the preserve."

The rule defines "beneficial hydrological functions" as "interactions between flora, fauna, and physical geological or geographical attributes of the environment, which provides benefits that

accrue to the public at large, including retardation of storm water flow, storm water retention, water storage, and periodical release." In defining essentially natural conditions the rule states that natural means pre-development, but one goal allows for existing conditions as an alternative to natural conditions. The rule makes explicit reference to beneficial hydrological functions, and the definitions refer directly to retardation of storm water flow, water storage, and periodic releases. These actions may become critical elements for the Estero Bay project.

The Estero Bay Aquatic Preserve Management Plan. Estero Bay was Florida's first aquatic preserve. In 1983, the Board of Trustees of the Internal Improvement Trust Fund adopted a management plan for the Estero Bay Aquatic Preserve, in a resolution designating the Bay as a "wilderness preserve" and stating that the primary management objective will be the maintenance of this ecosystem in an essentially natural state. The management plan identifies the preserve and lands seaward of mean high water. It also summarizes state law affecting preserves and preserve management, consistent with other sections of this report. The Plan adds 22 policy directives that provide staff direction for implementing the program. Directives pertinent to the development of research goals include:

1. Ensure the maintenance of essentially natural conditions to ensure the propagation of fish and wildlife, and public recreational opportunities;
2. Protect and, where possible, enhance threatened and endangered species habitat within the aquatic preserve;
3. Prohibit development activities within the preserve that adversely impact upon grassbeds and other valuable submerged habitat [within limits of a public interest test];
4. Require, through the efforts of DER and the water management districts the maintenance of the naturally high water quality of the estuary, and ensure the natural seasonal flow fluctuations of freshwater into the estuary.

The plan describes the resources of the preserve, stating that "the general conclusion...is that there is not now available sufficient water resource data to understand how the system operates or to identify the water quality problems existing now and for the future." The Plan points to a need for basic hydrological, chemical, and biological data on Estero Bay.

Chapter 17-4 Florida Administrative Code -- Permits creates a permitting system for construction and operation of air and water pollution sources and dredging and filling. It provides anti-degradation requirements for Outstanding Florida Waters and Outstanding National Resource Waters. It provides for temporary permits and mixing zones. This rule establishes the procedures and fees for permit application. Anti-degradation criteria in the rule include whether a proposed

discharge will adversely affect (a) conservation of fish and wildlife, including threatened or endangered species or their habitats, and (b) fishing or water based recreational values or marine productivity.

In OFW, the discharge must have a mixing zone as prescribed by 17-3.050 (1) (f) ii and by this rule (see below) and must singly or in combination with other discharges cause significant degradation of existing ambient water quality. Existing ambient water quality is defined as the best case between (a) that which, based on the best scientific information available, could be reasonably expected to have existed in the year of the OFW designation, or (b) that which existed in the year prior to the permit application. Either source shall include "daily, seasonal, and other cyclic fluctuations."

The rule allows for mixing zones but states that "no mixing zone...shall be allowed to significantly impair any of the designated uses of the receiving body of water." Some of the considerations for mixing zones include:

1. Condition of the receiving body of water including present and future flow conditions and present and future sources of pollutants;
2. The nature, volume, and frequency of the proposed discharge including any possible synergistic effects with other pollutants or substances which may be present in the receiving body of water;
3. A mixing zone shall not include a nursery area of indigenous aquatic life or any area approved by the Department of Natural Resources for shellfish harvesting;
4. In lakes, estuaries, bays, lagoons, bayous, sounds and coastal waters, the area of a mixing zone shall not exceed 125,600 square meters, and all mixing zones together shall not exceed 10 percent of an estuary's area;
5. The maximum concentration of wastes in the mixing zone shall not exceed the amount lethal to 50 percent of the test organisms in 96 hours (96 hr LC_{50}) for a species significant to the indigenous aquatic community.
6. Although largely a procedural rule it does provide some guidance useful to the present Estero Bay case, although it should be noted that board-approved works of a water management district are probably exempted from the permit requirements of this rule. Furthermore, the rule does not appear to speak to the discharge of fresh water per se.

Nevertheless, the rule provides insight to limits the state seeks in permitting new sources of pollutants to surface waters and these features may be instructive for Estero Bay. Considering fresh water as a pollutant, for example, the rule requires that the nature, volume and frequency of the proposed [fresh water] discharge including any possible synergistic effects with [fresh water already] present in the receiving body of water be considered. Likewise, a mixing zone [of fresh water] shall not include a nursery area of indigenous aquatic life or any area approved by the Department of Natural Resources for shellfish harvesting.

The rule states that in estuaries [and] lagoons the area of a mixing zone shall not exceed 125,600 square meters, and all mixing zones shall not exceed 10 percent of an estuary's area. It is presently not known whether 10 percent of Estero Bay's total surface area is affected by the "mixing zones" of canals. On the other hand, 125,600 square meters as a maximum mixing zone is equal to about 31 acres, or an area of the Bay enclosed by a radius of 935 feet from the mouth of the Estero or Imperial Rivers.

IV. Water Management District Guidance

Rules of the South Florida Water Management District. Highlights of selected rules are noted below for their applicability to the present project. Part B, Basis of Review for Surface Water Management Permit Applications, of Chapter 40E-1, General and Procedural, notes, "there are areas within the District where water considerations are extremely important, because of the sensitivity of the area. These areas include...Six Mile Cypress Strand and Estero Bay Aquatic Preserve in Lee County."

Chapter 40E-2, Consumptive Use, states that proposed uses will not cause significant saline water intrusion, adversely affect offsite land uses, will not cause adverse environmental impacts, or pollution of the water resource. Chapter 40E-23 designates all of the Estero Bay and watershed area as critical water supply problem areas, meaning that the areas have experienced or are anticipated to have water supply problems in the next 20 years.

District-hosted Estero Bay and Watershed Management and Improvement Plan Workshop resulted in a report by the Florida Growth Management Conflict Resolution Consortium. The workshop was attended by 25 environmental and civic organizations as well as agencies. The workshop identified opportunities and threats facing the bay, a vision for the bay, and strategies for achieving the vision. Action plans were developed for the most important strategies.

This is an interesting document insofar as the development of a research plan goes, for it demonstrates either a high level of knowledge about the bay, or the situation that perceptions about the bay are widely and strongly held. Highlights for the research plan include the view that regular water testing is underway by many groups, but must be coordinated better; that there is a pervasive disinterest and funding to collect data needed for proper scientific assessment, and that runoff and septic tanks are major threats to the Bay.

A vision for the Bay had these features-- that decision makers understand and support the economic and functional importance of Estero Bay and its watershed; that government buy more land and improve land use controls; that a comprehensive stormwater management program be funded, and that biological criteria for the health of the Bay be established. High priority strategies include exchange of monitoring data, mapping historic seagrass beds, implementing natural hydroperiods rather than "quick flushes." An action plan for the last strategy would determine historic

hydroperiods and establish and maintain a new hydroperiod realistic for today -driven by biological criteria established for the bay.

A survey of participants indicated that "fish" and boating were the bay's most valued assets. Habitat loss was a greater concern than water quality. The same survey found that polluted runoff was felt to cause more bay problems than habitat destruction, contra the previous statement. Ten mile canal and the two rivers were most often cited as problem areas, and the main cause cited for tributary

degradation was physical change (as opposed to stormwater). Regulation and treatment were cited as the most needed actions. Research was deemed the least needed.

Despite mixed messages contained in the report, its content is valuable for insight to issues and expectations that a research plan should address. The report also signifies a high level of commitment to action, rather than additional study, which may work against efforts by the ABM and District to implement recommended research.

The Corkscrew Regional Ecosystem Watershed Conceptual Management Plan describes existing lands and resources under active management, as well as prospective additions. A separate fire management plan is appended. The CREW Plan cites as its primary goal, "To protect the hydrologic and biotic resources of CREW, while allowing public use to the extent compatible with resource protection." Three hydrologic management goals are given, 1) maintain existing sheet flow and water quality conditions, 2) maintain existing wetland hydroperiods, and 3) maximize benefits to the downstream hydrologic system. These goals assert the CREW Management Planning Team's view that the maintenance of existing hydrologic conditions is favorable. The Plan also gives a wildlife management goal, "to ensure the perpetuation of viable populations of indigenous wildlife species through the implementation of sound management practices, giving special consideration to the needs of listed species." Listed species mean those plants and animals on federal or state lists whose populations are endangered, threatened, or otherwise at risk. The Plan names 104 listed species, a very high number compared to other sites of comparable size. The Plan makes an important link between Estero Bay and the large area of inland wetlands within the Bay's watershed, and calls attention to the importance of proper freshwater flows. On balance, the Plan is silent on matters of water quality.

The District's Identification of Priority Water Bodies within the South Florida Water Management District ranked all lakes, wetlands, and estuaries of south Florida, for designation as priority water bodies in the Surface Water Improvement and Management (SWIM) Program. Estuaries were ranked separately. Estero Bay received the highest ranking of all estuaries in south Florida. Under SWIM, two priority categories are recognized, preservation, and restoration. The District found that Estero Bay was the south Florida estuary most deserving of a preservation status. Goals for preservation water bodies under SWIM include:

1. Purchase of affected lands, adjacent buffer areas, flowage or other protective easements;
2. Improved wildlife management practices;
3. Restrictions on public access, boat use, marina siting, dock construction, port development, or navigational improvements, and (among others not quoted)
4. Construction of additional upland detention basins and flow management programs to improve the quality and timing of discharges to receiving water bodies.

Some bay tributaries were also designated as preservation water bodies, while others were designated as restoration water bodies. Findings are useful for Estero Bay science and management because of the Bay's high score relative to other south Florida estuaries. Values of the Bay are clearly meant to be preserved. The report also advances the District's continuing commitment to structural rather than non-structural approach to surface water management.

A. Although laws and rules of the State, it is instructive to introduce plan language affecting Estero Bay by noting these state acts authorizing regional and local government plans. Laws (Section 163.317 F.S.) and rules (Chapter 9J-5.012 F.A.C.) of the State establish policies and

B. objectives; require regional and local government plans addressing specified issues; require vertical consistency of plans; and provide for administration, implementation, and amendments to plans. Relevant State goals include:

1. Florida shall assure the availability of an adequate supply of water for all competing uses deemed reasonable and beneficial and shall maintain the functions of natural systems and the overall present levels of surface and ground water quality. Florida shall improve and restore the quality of waters not presently meeting water quality standards;
2. Florida shall protect and acquire unique natural habitats and ecological systems such as wetlands...and restore degraded natural systems to a functional condition. The Strategic Regional Policy Plan of the Southwest Florida Regional Planning Council contains text for each plan element required by state law, including these goals pertaining to science and management in Estero Bay:

IV-4. ...By the year 2005, each waterbody with a pollutant load reduction goal will meet or exceed the goal established for it.

IV-6. All effluent will meet or be better than all pertinent state water quality standards.

IV-8. Declining trends in quality or quantity of coastal resources will reverse due to the success of pollution control measures and restoration efforts.

IV-12. Drainage systems will be managed to maintain or restore natural timing pattern, and quality of freshwater flows of the watershed basin.

The Plan states that indicators of success in meeting Goal IV-8 are population levels of marine species; changes in the number of catches of juvenile commercial and recreational fish species, and change in the number of acres of sea grasses. The Plan states as one of the region's main concerns, "Is our natural drainage system contributing to our marine ecology in a manner consistent with historical direction, volume, timing, and quality?" Indicators for Goal IV-12 are number of tributaries with natural flow conditions. The Plan elsewhere states (page IV-39) that "Estero Bay...should be designated as a Priority "A" waterbody for the SWIM Program...". A number of other goals and policies indirectly speak to Estero Bay and should be considered in planning science or management programs. Taken as a whole, the Plan sets very high standards for Estero Bay.

The Estero Bay Agency on Bay Management is a non-regulatory body created to recommend management improvements in the Bay and its watershed. Draft Principles of the Estero Bay Agency for Bay Management identifies guiding principles to be utilized wherever and whenever possible, while realizing that some situations may not allow their strict adherence. A total of 83 principles are organized under categories of Water Courses, Uplands and Headwaters and Isolated Wetlands, and Bay Waters, including these of special usefulness for research planning:

1. No further channelization of remaining natural watercourses will occur.
2. A better balance of ecological needs versus water flow will be used for water resource management decisions.
3. Ancient relief of upper tributary reaches will be maintained by...preserving...characteristic riparian habitat and canopy...and tributary bank contours.
4. Grants or incentives should be provided for retrofitting old surface water management systems that are not effectively managing water volume of flow, or removing nutrients and other pollutants.
5. All urbanization will be served by centralized sewer systems.
6. Retrofitting existing shorelines hardened with vertical seawalls to sloping limerock revetments or native, salt tolerant vegetation, should be encouraged wherever possible.
7. No further alteration of Estero Bay bottom shall occur, except for public interest tests.
8. A manatee protection plan will be adopted.
9. Maintain and improve the overall ecology of the bay and its watershed.
10. Increase efforts to insure the sustained productivity of wildlife resources such as rookeries, sea grass beds, and fisheries.

The Lee County Comprehensive Plan addresses all mandatory elements. For the most current language, goals and objectives are quoted from the Evaluation and Appraisal Report of 1994. Goals and objectives are paraphrased to highlight their relevance to Estero Bay. Some plan elements and numbers may have changed as a consequence of subsequent amendments approved by the Lee County Commission.

- Objective 16.1 states that no further functional degradation of estuarine and wetland resources shall take place; an attempt will be made to improve water quality in Estero Bay to Class II standards by the year 2005.
- Policy 16.11 requires that a Matanzas Harbor Management Plan be promulgated, for a designated mooring area, trash and wastewater disposal, and a research and education facility for local waters.
- Goal 77. maintains and enhances native habitats, floral and faunal species diversity, water quality, and natural surface water characteristics.
- Policy 77.2.3 prevents water management and development projects from altering or disrupting the natural functions of significant natural systems.
- Objective 77.3 maintains and enhances the fish and wildlife diversity and distribution with the county for the benefit of a balanced ecological system.
- Objective 77.7 et seq. encourages study and regulatory protection for west Indian manatees.
- Objective 77.12 supports maintenance and improvement of marine fisheries productivity and promotes conservation of fishery resources through habitat protection and restoration.
- Policy 77.12.3 allows for unmarked channels or passages to be marked to reduce injury to marine seagrass beds.
- Goal 78 maintains or improves water quality and wildlife diversity in estuaries and reduces or maintains current pollution and system imbalances in order to conserve estuarine productivity.
- Objective 78.1 continues to establish baseline conditions in estuaries, including pollutant and freshwater loadings, and maintains an ongoing water quality monitoring program.
- Policy 78.1.1 emphasizes the need for monitoring in Estero Bay.
- Policy 78.1.1.4 intends to maintain or improve water quality in estuaries to meet state water body classifications; preserve waters approved for shellfish harvesting, and attempting to return viable "closed" (due to water quality) shellfishing areas to an "approved" status.
- Policy 78.1.3 monitors and reviews freshwater discharges affecting estuarine areas in order to maintain ...optimum productivity.
- Goal 78.2 et seq. prepares management plans for estuarine watersheds, with priority to the watershed of Estero Bay, "a critical estuary undergoing development impacts."
- Objective 85.1 maintains high water quality, meeting or exceeding state and federal water quality standards. New development and additions shall not degrade surface and ground water quality (Policy 85.1.2).

VI. Other Local Government and Private Guidance

Lee County's Surface Water Management Plan investigated conditions in each of the county's principal watersheds. Boundaries were described and sensitive lands were identified. Analyses are given for conveyance elements, hydrology, water quality, and water budgets. System capacity was analyzed and improvements were proposed. The Plan does not state goals, policies, or objectives per se, but does make recommendations under each watershed section and report element. Some provide guidance for the present effort and are paraphrased below.

In the Ten Mile Canal, a vegetated linear littoral system is proposed and a spreader system to divert water more broadly into coastal wetlands is suggested. Weed control is recommended. Use of excess water can reduced the volume of released water.

In the Estero River, Halfway Creek and Spring Creek watersheds, conservation easements along the streams should be acquired. Halfway and Spring Creek loads are expected to increase with development.

In the Imperial River watershed, water control structures are suggested. All of the waterfront development along the river and finger canals should be on central sewer (service). River hydroperiod and water quality should use historic levels as targets.
For the watersheds adjoining Estero Bay in general, the Plan recommends increased or continued monitoring, removal of shoreline vegetation, improved conveyances of flood waters to the Bay, and case-by-case improvements for water quality. The general effect of the Plan will be to increase freshwater flows to the Bay, especially during flood periods. Preliminary modeling indicates that many forms of nutrients or contaminants will not increase as land development proceeds, which results will require refinement through improved monitoring and modeling.

The South Lee County Watershed Plan resulted from catastrophic flooding in 1995. Four of its eleven goals are relevant to Estero Bay:

- Restore historic surface water flow characteristics where practical, with special emphasis on conservation and public lands.
- Reduce the impact of excessive freshwater discharges on downstream estuaries, and
- Coordinate with other regional studies (Estero Bay Project,
- Big Cypress Basin Watershed Plan).

The Plan acknowledges the usefulness of using historic flow characteristic as a model for restoration, and is sensitive to the potential harm that can result in Estero Bay from excessive freshwater discharges.

A report, "Managing the Quality, Quantity, and Timing of Surface Water Discharge into the Estero Bay State Aquatic Preserve" by W. Dexter Bender and Associates, reviews climatic factors, governmental infrastructure, performance standards, Estero Bay issues, and strategies and techniques. The private report states the primary goal for Estero bay should be to "preserve and

conserve the overall existing system with restoration in specific areas." Recommended strategies, paraphrased for brevity, include:

1. Freshwater discharge should mimic rainfall patterns.
2. Direct freshwater discharge should be diverted to near the head of natural tidal streams where those basins receive less than historical amounts.
3. Direct freshwater discharge into the Bay should be diverted to spreader systems.
4. Fixed weir/drop structures may need variable elevation controls.
5. Interbasin transfers of freshwater out of the Estero bay system should be considered.

6. Nutrient additions should be considered relative to the Bay's capacity for assimilation.
6. Sediments should be prevented from reaching the Bay.

1.3.3 Assessment of Authorities

Valued ecosystem components of Estero Bay may be identified from the authorities reviewed in the previous section, as well as from general estuarine ecology and experiences of other Florida bay management programs. Estero Bay authorities refer to numerous living resources and ecosystem components, captured most thoroughly by the Aquatic Preserve Management Plan: sponges, soft coral, hard coral, submerged grasses, mangroves, salt water marshes, fresh water marshes, mudflats, estuarine, aquatic and marine reptiles, game and non-game fish species, estuarine, aquatic and marine invertebrates, estuarine, aquatic and marine mammals, birds, shellfish, and mollusks. Authorities repeatedly value ecosystem processes that underlie biotic resources, in particular a natural hydroperiod, and high water quality.

This palette of valued ecosystem components may be simplified somewhat by recognizing primary producers (such as seagrasses and mangroves); lower consumers-- usually benthic fauna (shellfish and other invertebrates, including shrimps and crabs); and higher consumers (fishes, birds, marine mammals), plus natural or historic levels of hydroperiod and water quality.

Despite the ambiguous status and trend of seagrass in Estero Bay, much commends its consideration as a valued ecosystem component. SAT (including rooted macroalgae) is a primary producer, and a unique habitat for many valued species. Many aspects of SAT biology are known, and models exist for their study in new areas. SAT presents attributes (location, area, species composition, depth distribution) amenable to hind-casting as well as forecasting. SAT has been used as a management objective in other Florida bay management programs, with success. In Tampa Bay, for example,

seagrass recovery was deemed feasible after discovering factors responsible for light attenuation in the Bay, and the dependence of water clarity on nitrogen load reductions.

Mangroves are mentioned directly and indirectly by several authorities, and from principles of estuarine ecology deserve such notice. On the other hand, there is a sentiment expressed in these authorities that preservation of existing mangroves, already achieved through a number of regulatory and other programs, is sufficient. But estuarine science strongly suggests that the large area of mangroves in and around the Bay, combined with the Bay's shallow nature, make mangroves an important factor in regulating Bay hydrology, water quality, and biological productivity. If so, we need to know what these regulatory effects are in order to understand how the Bay functions, or will respond to management alternatives. Given the inseparable link between mangrove ecosystems and the geology of south Florida, mangroves are likely to figure prominently in the geology of Estero Bay. As a result, later remarks regarding the geology of Estero Bay should be interpreted to refer to mangrove systems, as well.

Lower consumers such as shellfish and crustaceans have ecological, recreational, and commercial value. Oysters, though not approved for consumption in Estero Bay, form reefs that are valuable habitat for many species of fishes. Oysters are sedentary, making them good indicators of water quality. Like SAT, oysters present attributes (location, area, condition, size, depth distribution) amenable to hind-casting as well as forecasting. Oysters have also been used as a management objective in other Florida bay management programs, with success. In the St. Lucie River estuary, for example, damaging levels of freshwater discharge were gauged according to the survival ability of oysters. Hard clams have been used in the Sebastian River and Indian River Lagoon for the same type of assessment. Shrimps and crabs are harvested for consumption, and are primary prey species for fishes, but the mobility of these animals limits their analytical usefulness as valued ecosystem components. The same limitation applies to higher consumers.

Natural hydroperiods and good water quality have been mentioned as valued ecosystem components. The metrics for these attributes are known. A natural hydroperiod can be calculated through modeling of pre-development conditions. State water quality standards can be used as straight-forward indicators of pollution. Their use in Estero Bay presents some difficulties, however. The topography, water budget, and discharges of the modern watershed are incompletely known. Hind-casting models will face difficult assumptions in the absence of historic data. Water quality criteria do not address nutrients (nitrogen, phosphorus) in empirical terms. Nutrients may not cause ecological imbalance, and this standard must therefore be interpreted using data on living resources such as seagrass. Moreover, there are no standards or criteria for salinity.

These difficulties could be addressed by recognizing oligohaline habitat as a valued ecosystem component. Oligohaline water has a salinity less than 10 parts per thousand (ppt). Seawater has a salinity of about 35 ppt. Oligohaline waters occur in and near sources of freshwater outflow. Their spatial extent and persistence integrate the effects of hydrology and water chemistry. Oligohaline

water is amenable to statistical and other types of modeling. As the fulcrum between the land and the Bay, metrics of oligohaline water can serve as "canaries" indicating the net interplay of runoff and tides. Oligohaline water is an essential habitat for the successful completion of many species' life cycle, but sudden or persistent excursions of oligohaline waters into bays harm overall estuarine productivity. Moreover, nutrient enrichment is often expressed as harmful algal blooms or oxygen depletion in low salinity waters, before being expressed in open bay waters. Metrics of oligohaline water could also fulfill the call by authorities for meaningful ecological indicators for the Bay.

Social expectations for Estero Bay are very high, and go far beyond maintenance of the status quo. The Bay is a Florida Aquatic Preserve and Outstanding Florida Water. The State of Florida intends that the aquatic preserve be managed for wilderness purposes. The OFW designation requires that no degradation of water quality be allowed. The South Florida Water Management District gave Estero Bay the highest ranking among estuaries for SWIM status, as a preservation priority. Lee County seeks to meet all established pollution load reduction goals for the Bay, and to work toward Class II (waters of the state) classification-- meaning that shellfish waters would be opened. Numerous authorities codify an intent to establish natural, historic, or pre-development conditions with respect to hydrology and water quality.

At face value, then, a review of bay authorities finds that social expectations for Estero Bay are more ambitious than any stated for most other bay management programs in Florida. The same authorities acknowledge that scientific understanding of the Bay must be increased, but in reality the desire for new understanding has far out paced the rate at which studies have been conducted.

1.4 Recommended Goals for the Estero Bay Research Plan

1.4.1 Remarks

A few points must be made as introduction to the research goals for Estero Bay, as these color the form and content of the goals. First among these is the inescapable need for goals to address the widely-held management intent to achieve natural, historic, or pre-development conditions in Estero Bay. No inference is drawn that existing physical changes to the Bay, such as development, are to be undone. Is it possible then, or desirable, to seek natural conditions? For the most part, the answer is yes.

It is highly desirable to seek such a goal from a scientific standpoint. The Bay's present condition largely reflects its original condition, and natural conditions of the past are knowable through historic records, proxy records, hind-casting, and modeling. Another reason is that the Bay as a system has evolved under a particular combination of physical and chemical conditions, few of which have changed significantly due to the works of humans. When perturbed, the tendency of Estero Bay is toward its structural and functional condition prior to the perturbation. Also, there is little evidence

that estuaries "adapt" to profound changes in their structuring influences; they instead persist at sub-optimal levels.

The most compelling point to be discovered in the progress made thus far toward developing an Estero Bay research plan will no doubt be the least expected among many bay investigators or enthusiasts, and it is this:

> *Geological structures and processes*[2] *in the bay, watershed, and inshore shelf are [probably] the dominant regulators of Estero Bay's hydrology, water quality, and ecology. Impacts of stressors (altered freshwater inflow, nutrient loadings, contaminants) or trends in valued ecosystem components (seagrasses, fish and wildlife) can be understood and managed only by understanding factors which control the Bay's geomorphology.*

A number of geological factors almost certainly affect most aspects of the Bay's natural processes. Surface water hydrology and water quality are affected by inland topography and soils. Capstone beneath the Bay may affect groundwater efflux. Seasonal and annual variations in sea level must affect the Bay's circulation profoundly, with cascading effects on water quality, seagrasses and mangroves, and larval recruitment and retention.

Estero Bay's shallow nature is the key to its science and management. Compared to other Florida estuaries, the Bay is very much shallower. Its tidal prism is much greater than tributary inflow under most conditions, yet it has a proportionately larger watershed than other estuaries (Figure 1). The Bay is not merely shallow. It lacks any sign of down-cut channels beyond the mouths of its tributaries, and tidal inlet channels are weak, and short.

As mentioned previously, some disagreement exists regarding the original abundance of seagrasses in the Bay. Yet, the shallow nature of the bay does allow for the possibility that seagrasses a) never were abundant, or b) were abundant but have declined in response to changes in the elevation of the bay bottom. These are speculative interpretations, but other lines of evidence suggest the possibility of depth regulation of seagrasses. In Sarasota Bay, seagrasses do not grow as deeply in areas with higher nutrient loads, than areas with lower loads. Given the large watershed-to-bay ratio in Estero Bay, and as-yet unconfirmed trends of increasing nutrient loading from the watershed, seagrasses may have declined, or be declining, as a result of the Bays' shallow nature.

Most of what has been written of Estero Bay's resources and issues treat the bay's geology as a formless, stable tableau across which flows or nutrient loads have changed, or biological attributes have declined. We need to know how it is that Estero Bay maintains its shallow nature, if such is the case, especially in the face of rising sea level. We need to know where bay sediments originate,

[2] Including mangroves.

how they are transported, and why they are deposited. Are sediments dominated by calcium carbonate, or quartz? Could bivalves in the bay and shallow Gulf be responsible for supplying the bay with sediment? If the sediment originates inland, how has it reached the bay given the rivers' low relief and typically low discharges? What are the implications for circulation, water quality, or biology, of seemingly unimportant channel improvements?

In the research goals to follow, geological foundations of valued ecosystem components have been included, to reflect the hypothesized importance to resource management of Estero Bay's geomorphology.

1.4.2 Recommended Goals

Goals recommended for the development of the Estero Bay Research Plan are given in Table 2. Three primary goals are established, for the valued ecosystem components of submerged aquatic vegetation, shellfish, and oligohaline habitats. Each is meaningful in the context of Bay management. Each is verifiable through empirical measurement, and each is practical (achievable with existing technology). Primary goals address primary and secondary producers at the species, community, and habitat levels of biological organization. Each is traceable through intermediate goals to major management issues of freshwater inflow, and water quality.

Restoration of historic conditions for submerged aquatic vegetation creates an opportunity to settle uncertainties that presently accompany trend analyses. Historic conditions may prove to equal or exceed modern conditions, but either outcome will have significant implications for Bay management. It is also possible that some SAT metrics (area, location) have changed while others (species composition, condition) have not, and such distinctions would be essential to discover.

Achieving the primary goal for SAT will require that goals be met for proximate stressors of SAT. Research questions will be needed that address multiple possible sources of turbidity in this shallow Bay. Direct exposure stress also will need investigation. Within the geological setting, structure, and processes affecting the Bay, it will be necessary to learn the extent to which the quantity and quality of freshwater inflows to the Bay regulate proximate stressors.

Improving the shellfish status of Estero Bay requires knowledge of existing shellfish resources, as well as general water quality and surface water sanitation. Research questions can make good use of existing information on oysters, hard clams, and other dominant bivalves. Needed will be data on circulation, water quality, and primary production, all traceable back to freshwater quantity and quality issues. Data on sources, transport, and fates of pathogens also will be needed.

By the same token, the goal of registering oligohaline habitats to their proper landscape position generates a number of research questions regarding freshwater quantity and timing. Taken as a whole, research questions generated for all eight goals should guide the definition of analytical

methods which, if implemented in the second phase of the Estero Bay Assessment, may be expected to generate information useful in the definition of water quality and water quantity objectives, or pollution load reduction goals for the Bay.